COMPUTERS IN AGRICULTURE

Computer Use and Satisfaction by Great Plains Producers: Ordered Logit Model Analysis

J. C. Ascough II,* D. L. Hoag, G. S. McMaster, and W. M. Frasier

ABSTRACT

Agronomists rely increasingly on computers, and more than half of all producers have access to computers. Increasing farm computer ownership has resulted in intensified efforts to transfer new software technologies to producers; however, little is known about how satisfied producers are with computers and the extent to which computers are actually used. We extended our 1996 survey of Great Plains producers to examine producer computer use and satisfaction and discuss potential implications for agricultural software developers. Building on our earlier computer adoption research, we developed ordered logit models for user satisfaction, frequency of computer use, and number of software applications used. Despite using more robust ordered logit models that fit the data well, surprisingly few explanatory variables were significant. Greater computer skill significantly increased user satisfaction and number of software applications used. Greater education also increased user satisfaction and number of software applications used but reduced frequency of computer use. Farming experience showed similar conflicting results as education, i.e., greater number of years farming resulted in significantly increased computer satisfaction but lower frequency of use and number of software applications used. A few other explanatory variables (e.g., farm owner or operator as the primary computer user had a significant positive influence on frequency of use) were important in one of the three ordered logit models, but no consistent relationship between models was found. Generally, greater frequency of use and computer skill increased perceived usefulness of computers by producers. Implications of these results for agricultural software developers are discussed in the paper.

Computer use among agronomists and other agricultural professionals has risen rapidly in the past decade. In *Agronomy Journal* alone, more than 40 papers related to agricultural software programs were published in the 1990s (e.g., GUICS by Acock et al., 1999; Magari and Kang, 1997; Michel and Radcliffe, 1995; NEPER-Weed by Schulthess et al., 1996; Smith et al., 1996; HERB by Wilkerson et al., 1991). Published software applications ranged from simulation models to yield mapping analysis tools. A natural consequence of increasing farm computer ownership is to intensify efforts to transfer new software technologies to producers. However, as agronomists and others proceed with developing and transferring software technologies to the field, it is important to improve our understanding of which producers use computers and how (or if) new software technology will be used.

Agricultural producers lagged behind other businesses in computer ownership and use in the 1980s, but observers predicted that ownership would increase dramatically in the 1990s (Batte et al., 1990; Schmidt et al., 1994; Woodburn et al., 1994), and indeed it has. The most recent USDA National Agricultural Statistics Service (NASS) farm computer usage survey (USDA-NASS, 2001) found that 55% of farms had computer access, up from 47% in 1999 and 38% in 1997. Current adoption of computers by producers now appears to match the general population (USDA-NASS, 2001). Despite rapid adoption of computers by agronomists and producers alike, little is known about why farmers purchase computers, what they use them for, and whether computers are making a positive impact on farm profitability. Software development for agricultural producers is costly; therefore, it seems prudent to clearly understand how producers might use computers before investing in technologies that may not be accepted. Three key questions that should concern developers of producer-oriented agricultural software are:

1. Which producers are using computers, and how do they use them?
2. How satisfied are producers with their computer's contribution to their agribusinesses?
3. What are the trends in the preceding questions and future implications for agricultural software developers?

Previous studies have focused on explaining which producers adopt computers (Putler and Zilberman, 1988; Willimack, 1989; Woodburn et al., 1994). A few studies have examined whether producers were satisfied with their computers and how they used them in their businesses (Baker, 1992; Batte et al., 1990). Amponsah published the last survey about the specifics of use or satisfaction, other than ours, in 1995. A multistate effort was conducted by the North Central Regional Research Committee, Farm Information Systems (NC-191), in the early 1990s in which 750 producers in each of 13 states were surveyed (Batte, 1995). Most regional studies were conducted on agricultural computer use between 1986 and 1991 (Ascough et al., 1999) and commonly found that farm size (hectares), farm income (or sales), ownership (tenancy), and education had positive effects on computer ownership and that age had a negative or sup-

J.C. Ascough II and G.S. McMaster, USDA-ARS-NPA, Great Plains Syst. Res. Unit, 301 S. Howes St., Room 353, Fort Collins, CO 80521; and D.L. Hoag and W.M. Frasier, Dep. of Agric. and Resour. Econ., B-329 Clark Bldg., Colorado State Univ., Fort Collins, CO 80523. Received 26 Feb. 2001. *Corresponding author (ascough@gpsr.colostate.edu).

Published in Agron. J. 94:1263–1269 (2002).

Abbreviations: NASS, National Agricultural Statistics Service.

pressing effect. Other variables found to have an impact on adoption were farm complexity, debt/asset ratio, exposure or perception that risk is important, and crop or livestock farm type (Putler and Zilberman, 1988; Batte et al., 1990; Jarvis, 1990; Baker, 1992; Woodburn et al., 1994). Some studies found that these same variables also contributed to computer satisfaction and use (e.g., Putler and Zilberman, 1988; Batte et al., 1990; Amponsah, 1995).

To assess the value of computers on farms, we conducted a random survey of Great Plains producers in the summer of 1996. An evaluation of which producers adopt computers and what type of hardware and software they use has already been published in Ascough et al. (1999) and Hoag et al. (1999). In this paper, we focus on the second and third questions: Once a producer has purchased a computer, how satisfied are they with its contribution to their agribusiness, and what are the resultant implications for agricultural software developers? In general, we are interested in addressing these questions for the purpose of guiding future software development and educational programs for farm applications.

Besides the information provided about computer use and satisfaction, this study contributes to the literature in two ways. First, all influential variables identified in both adoption and satisfaction studies, such as education level, producer age, and farm size, were investigated in our survey. Previous studies did not look at both adoption and satisfaction, which are likely related. Second, we use an improved estimation technique (ordered logit) compared with the multinomial logit technique used in previous studies and apply it to all three methods used previously in the literature to measure use and satisfaction: (i) a self-appraisal of computer usefulness, (ii) frequency of computer use, and (iii) number of software applications used.

MATERIALS AND METHODS

The Great Plains contains 398 counties in 10 states: Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, and Wyoming. The 1996 survey covering this region was conducted using Dillman's (1978) total design method; complete survey details are described in Ascough et al. (1999) and Hoag et al. (1999). A random list of 800 Great Plains producers was provided by USDA-NASS; the list was divided into four groups based on type and size of operation: small crop, large crop, small livestock, and large livestock (small was less than \$100 000 in gross annual farm sales). Surveys were mailed to a total of 772 usable addresses, and 219 completed surveys were returned. The response rate of 28.4% was lower than expected but comparable to other studies [Batte et al., 1990 (40%); Woodburn et al., 1994 (35%); Amponsah, 1995 (31%)]. We believe our low response rate reflects a high number of producers in the NASS database that are part-time, small producers (about 72% of the database) who might not have responded because they do not perceive themselves as farmers.

The survey was divided into five sections with a total of 26 questions. The relevant sections of the survey for this study were:

- *Producer information*. Information about producers, including age, education, off-farm employment, and production experience and about their operation, including farm size, gross sales, and commodities produced. Also, whether they owned a personal computer (PC) and, if not, why? And were they likely to buy one in the future?
- *Computer ownership*. Information about the producer's computer system, including processor speed, hard drive size, year purchased, whether the computer had a CD-ROM, and if the Microsoft Windows operating system was used.
- *Usefulness of computers*. The primary computer user was identified, and users' skill level, where they learned to use a computer, and the software applications they used most frequently (e.g., taxes, word processing, production records, etc.) were determined. They were also asked to indicate how useful they found the computer to be in their agribusiness.

Measuring computer use and satisfaction can be difficult, and interpretation is often unclear for many reasons. Some researchers have addressed computer use by asking producers if they were satisfied with their computers (Batte et al., 1990), which makes sense in the initial stages of ownership where uncertainty is high. However, ownership and satisfaction become highly correlated over time as producer experience grows. Therefore, we asked our 1996 sample of computer owners about the intensity of their satisfaction, hedging that most would be satisfied because computers have become more infused into production agriculture. In addition, we looked at two measures of computer use: frequency of use and number of applications used, which also may be proxies for computer value (Batte et al., 1990; Baker, 1992). Measures of use also may indicate the degree of satisfaction.

Baker (1992) and Amponsah (1995) used a binary yes-or-no question to ask producers if they thought computers were useful; however, this ignores how intense the user is in their belief. To provide more information, respondents to this survey were asked to select answers from a Likert scale where computers are 1 = not worth the effort, 3 = useful but don't increase profits, and 5 = useful and increase profits. Intermediate values of 2 and 4 could also be circled.

Batte et al. (1990) and Baker (1992) examined computer use by dividing the number of software applications a producer used into categories such as 0 to 3, 4 to 5, and 6 to 8. This procedure suffers from three limitations: (i) The number of software applications is assumed to be a good proxy for use; (ii) the number of applications is divided into arbitrary categories; and (iii) this method only provides the relative probability comparison between two categories, for example, 0 to 3 compared with 4 to 5. To improve on this measure of use, we asked producers directly how frequently they used their computers for their agribusiness. Frequency of use for farm-related decisions was solicited from producers by asking them if they used the computer daily, weekly, monthly, or a few times a year. To maintain compatibility with previous studies, we also evaluated a second measure of use, the number of software applications used.

Ordered Logit Models for Computer Use and Satisfaction

Logit is one of several models commonly used to solve discrete-choice problems (Davidson and MacKinnon, 1993; Greene, 1999). The standard form of the multinomial logit model is:

$$\log [P/(1 - P)] = \alpha_o + \Sigma\alpha_i X_i + \varepsilon \qquad [1]$$

where P is the probability that the dependent variable Y =

1; $(1 - P)$ is the probability that $Y = 0$; α's are parameter estimates for the independent variable, X_i, which influences the dependent variable; and ε is the unexplained random component. This model relies on the logistic cumulative probability distribution to represent the impacts of explanatory variables on the probability of adoption. There are numerous logit modifications to suit special cases. The empirical analysis herein relies on ordered logit, which is an improvement on multinomial logit as used in previous studies.

In this study, all three measures of use and satisfaction are ordered scales where $1 < 2 < 3$ and so on. The ordered logit model extends traditional multinomial logit models by allowing the dependent variable to have more than two possible outcomes that are ordinal in nature. As Greene (1999) explains, the expected model is built around the latent model:

$$y^* = \alpha_o + \Sigma\alpha_i X_i + \varepsilon \qquad [2]$$

where y^* is unobserved; but we do observe:

$$\begin{aligned} y &= 0 \quad \text{if} \quad y^* < 0 \\ y &= 1 \quad \text{if} \quad 0 \leq y^* < \mu_1 \\ y &= 2 \quad \text{if} \quad \mu_1 \leq y^* < \mu_2 \\ &\vdots \qquad\qquad \vdots \\ y &= J \quad \text{if} \quad \mu_{J-1} < y^* \end{aligned} \qquad [3]$$

where J is the number of categories.

The ordered logit algorithm simultaneously estimates the parameter vectors for α and μ. The estimated μ's indicate the dividing lines between $Y = 0$ and 1 (μ_0), $Y = 1$ and 2 (μ_1), $Y = 2$ and 3 (μ_2), and so on for the probability that an outcome is 1, 2, 3, or more. There will be two fewer μ's than outcomes Y. If the μ's are significant, the estimation can be used to divide responses into the ordered outcome categories with confidence. Standard goodness-of-fit tests for logit models include t tests for the estimated coefficients, Chi-square and likelihood ratio tests on the hypothesis that all variables are zero, and the McFadden R^2, which is an adjusted R^2 to fit the nonlinear logit procedure. Another standard test is to provide information about prediction success. Prediction success indicates the proportion of user (survey) responses that the logit model correctly predicts from the original data.

Three ordered logit models were estimated to explain: (i) factors contributing to a producer's perceived usefulness of computers (satisfaction), (ii) frequency of computer use, and (iii) number of software applications used. Logit names for the dependent variables (representing the three ordered logit models) are listed in Table 1 as USEFUL, OFTEN, and NUMAPPS, respectively. The set of explanatory (independent) variables and their corresponding names for the three ordered logit models are also listed in Table 1. The explanatory variables are grouped into classes representing the following survey information: (i) farm operator characteristics (personal), (ii) farm complexity, (iii) farm type, (iv) computer operator characteristics, (v) computer learning methods, and (vi) computer hardware. Frequency of use (OFTEN) was included as an explanatory variable in the model of perceived usefulness because how often computers are used should influence their usefulness. In addition, usefulness (USEFUL) was an explanatory variable for the frequency of use and number of software applications used logit models because these should be positively correlated to usefulness.

The computer operator's skills likely affect the farm operator's view of computers by directly influencing how much the computer has to offer. The producer's view may also be enhanced if the farm operator is the primary computer user. Producer self-rated skill level is represented by the independent variable PCSKILL in the logit models (Table 1). Furthermore, how computer operators learned to use a computer may also affect their perceptions. If a particular learning method is more effective, perceptions and use would likely increase. Five learning methods were used as binary variables, including course or seminar, tutoring, government workshop, friend, and self-taught. These independent variables are represented as LEARN 1 through 5, respectively, in the logit models (Table 1).

Finally, quality of computer hardware available to the user may affect use and satisfaction. Many variables were elicited regarding computer capabilities: main processor type, memory, disk storage, operating system, and peripherals. However, because of the dramatic increase in computer technology over time, it was found that the year that the current computer was purchased provided the most concise representation of the capability of the computer platform. This variable is represented as COMPYEAR in the logit models (Table 1).

COMPUTER USE AND SATISFACTION RESULTS

A variety of ordered logit model specifications (Table 2) were tried for computer satisfaction (USEFUL), frequency of computer use (OFTEN), and the number of software applications used (NUMAPPS). Two criteria were used to determine the final ordered logit models: Explanatory variables that were strongly correlated were eliminated, and explanatory variables with asymptotic t ratios <1 were eliminated if an F test could not reject the hypothesis that the new model was identical to the old model. Therefore, several variables in Table 1 were not used for final logit model estimation. The explanatory variables representing a respondent's age (AGE) and farming experience in years (EXPYRS) were highly correlated ($r = 0.747$). Likelihood ratio hypothesis tests showed that using EXPYRS alone was not significantly different from using both AGE and EXPYRS but was significantly better than using AGE alone. Thus, AGE was dropped from the set of explanatory variables in favor of EXPYRS. The variables indicating off-farm employment (FULLTIME) and holding an off-farm job that used a computer (JOBCOMP) were also highly correlated ($r = 0.855$). Likelihood ratio hypothesis tests indicated no significant penalty for dropping either variable; however, both variables exhibited poor explanatory power and were summarily excluded. Because of poor predictive ability, the LEASED, FULLTIME, NUMENTRP, and LEARN 1 through 5 explanatory variables also were not used for final logit model estimation. There were 64 responses that were complete for the USEFUL and OFTEN logit models and 60 responses that were complete for the NUMAPPS logit model.

Goodness-of-fit measures indicate that all three of the estimated logit models fit the data reasonably well. The Chi-squared statistics are all significant at the $\alpha = 0.01$ level (data not shown). The McFadden R^2 statistics for the logit models ranged from 0.22 to 0.26, which compares favorably to similar studies using logit (Putler and Zilberman, 1988; Batte et al., 1990; Baker, 1992). Overall prediction success results are presented for each logit model and for how often each model correctly

Table 1. Explanatory variables considered for computer use and satisfaction ordered logit models.

Variable	Logit name	Possible values
	Dependent	
Perceived usefulness of computers	**USEFUL**	**0 = not useful or useful but doesn't increase profits**
		1 = intermediate
		2 = useful and increases profits
Frequency of computer use	**OFTEN**	**0 = a few times a year**
		1 = monthly
		2 = weekly
		3 = daily
Number of software applications used	**NUMAPPS**	**0 = one or two applications**
		1 = three or four applications
		2 = five or six applications
		3 = seven or more applications
	Explanatory	
Personal		
Operator age	**AGE**	**Years**
Operator education	**EDU1**	**1 = some high school**
	EDU2	**1 = technical or vocational degree**
	EDU3	**1 = some college**
	EDU4	**1 = BA or BS degree**
	EDU5	**1 = graduate degree**
Operator farming experience	**EXPYRS**	**Number of years of farming experience**
Operator computer exposure	**JOBCOMP**	**1 = yes if use computer in off-farm job**
Farm complexity		
Farm size	**ACRES**	**Number of hectares in operation**
Annual gross sales	**SALES**	**0 = <\$100 000, 1 = \$100 000–\$499 999**
		2 = \$500 000–\$1 000 000, 3 = >\$1 000 000
Tenure	**LEASED**	**Percentage of farm leased**
Management focus	**FULLTIME**	**1 = no off-farm job**
Farm type		
Number of enterprises	**NUMENTRP**	**Number of major enterprises identified**
Commodity mix	**CROPS**	**1 = one or more cropping enterprises**
	LVSTK	**1 = one or more livestock enterprises**
Computer operator characteristics		
Operator's self-appraised skill	**PCSKILL**	**0 = beginner, still learning just a few programs**
		1 = possess the basic skills
		2 = very familiar with the programs used
		3 = advanced, comfortable learning new software
Primary computer user	**OPERATOR**	**1 = owner or operator is primary computer user**
Perceived usefulness of computers	**USEFUL**	**See dependent variables above**
Frequency of computer use	**OFTEN**	**See dependent variables above**
Learning methods		
Took course or seminar	**LEARN1**	**1 = used this method, 0 otherwise**
Commercial tutoring	**LEARN2**	**1 = used this method, 0 otherwise**
Government agency (i.e., Extension)	**LEARN3**	**1 = used this method, 0 otherwise**
Learned from friends	**LEARN4**	**1 = used this method, 0 otherwise**
Self-taught (manuals, trial-error)	**LEARN5**	**1 = used this method, 0 otherwise**
Computer hardware		
Year current computer purchased	**COMPYEAR**	**Years 1980–1996**

predicted discrete subcategories [e.g., USEFUL (0–2), OFTEN (0–3), and NUMAPPS (0–3)]. Prediction success is an intuitive way to gauge model performance, that is, original data are used to test the percentage of times that the fitted logit model correctly predicts a response within a particular category or outcome. For example, if a model had three discrete outcomes, any prediction above a 33% success rate would be an improvement over chance; any prediction above a 25% success rate is an improvement over chance for a model with four discrete outcomes. Table 2 shows that overall prediction success ranged from 51.7% for the number of software applications used model (NUMAPPS) to 54.7% for the frequency of computer use model (OFTEN) to 64.1% for the user satisfaction model (USEFUL)—these results are consistent with other logit studies that have measured use and satisfaction (Putler and Zilberman, 1988; Batte et al., 1990; Baker, 1992). Partial R^2 tests for multicollinearity in model formulation were all <0.75, indicating that multicollinearity was not a problem. Seven explanatory variables were significant in the three logit models; the lack of significant explanatory variables can be explained in part by data limitations. Because computer ownership is highly correlated to computer use, we focused on measuring the degree of satisfaction or use, which is more difficult to discern than a simple yes or no response.

Farming experience (EXPYRS), the computer operator's self-appraised skill (PCSKILL), and the frequency of computer use (OFTEN) were statistically significant in the user satisfaction model (USEFUL; Table 2). Other important coefficients (indicated by higher asymptotic t-ratio statistics) suggest that producers with a graduate school education and newer computer equipment find computers more useful. Overall prediction success for the USEFUL model was 64.1%, but the model predicted whether users did not find a computer useful at all (85% correct) much better than it distin-

Table 2. Ordered logit model analysis of computer use and satisfaction for Great Plains producer survey.

			User satisfaction (USEFUL)			Frequency of computer use (OFTEN)			Number of software applications used (NUMAPPS)	
Variable	Mean		Coefficient estimate	Asymptotic *t* ratio		Coefficient estimate	Asymptotic *t* ratio		Coefficient estimate	Asymptotic *t* ratio
Constant			−25.47†	−1.71		4.06	0.366		−8.76	−0.778
EXPYRS	23.850		0.053†	1.88		−0.057	−1.58		−0.047	−1.48
EDU2	0.113		−0.506	−0.481		0.085	0.062		1.81†	1.69
EDU3	0.226		0.107	0.118		−0.634	−0.786		0.234	0.306
EDU4	0.359		0.715	0.933		0.488	0.656		1.18	1.44
EDU5	0.113		2.62	1.63		−1.96	−1.62		1.00	0.989
ACRES	1335.285								0.001	0.856
SALES	1.792								0.803†	1.71
CROPS	0.887					1.24	1.41			
LVSTK	0.623		0.719	1.03						
PCSKILL	2.509		0.594†	1.86		0.589	1.50		0.656†	1.73
OPERATOR	0.717		−0.951	−1.24		2.31**	2.81		1.10	1.47
USEFUL	1.019					1.12*	2.13		0.735†	1.94
OFTEN	1.075		1.36**	2.64						
COMPYEAR	91.810		0.241	1.52		−0.071	−0.584		0.076	0.653
Number of observations			64			64			60	
McFadden R^2			0.24			0.26			0.22	
Log likelihood (LL)			−52.07			−59.68			−62.26	
Restricted LL			−68.72			−80.26			−79.33	
Model Chi-square			33.30			41.16			34.14	
Prediction success, %		Total	64.1		Total	54.7		Total	51.7	
		USEFUL = 0	84.6		OFTEN = 0	68.2		NUMAPPS = 0	25.0	
		USEFUL = 1	0.0		OFTEN = 1	54.5		NUMAPPS = 1	52.6	
		USEFUL = 2	46.9		OFTEN = 2	43.8		NUMAPPS = 2	61.9	
					OFTEN = 3	25.0		NUMAPPS = 3	50.0	

* Coefficients are significantly different from 0.0 at $\alpha = 0.05$.
** Coefficients are significantly different from 0.0 at $\alpha = 0.01$.
† Coefficients are significantly different from 0.0 at $\alpha = 0.10$.

guished between whether it was intermediate or highly useful (correct 0 and 47% of the time, respectively). The USEFUL model maximized overall prediction success by predicting that all responses would fall into categories 0 (not useful or does not increase profits) or 2 (useful and increases profits). No responses were predicted for the intermediate category 1 (i.e., that computers were in between not useful and useful). These results suggest that we can predict very well producers who do not find computers useful and, to a lesser degree, highly useful, but we have no indication of the group who found them of intermediate value.

Table 2 shows that the frequency of computer use logit model (OFTEN) was significantly affected by the farm operator being the primary computer user (OPERATOR) and the perceived usefulness of computers (USEFUL). Interestingly, those producers with more farming experience and advanced education are likely to use the computer less often, as shown by the negative coefficient estimates for EXPYRS and EDU5. Also, the computer is used more frequently in cases where the farm manager is the primary computer operator. While significant at a lower level, the OFTEN logit model suggests there is a positive relationship between frequency of computer use and the operator's computer skill (PCSKILL). The explanatory variable coefficient estimate for one or more cropping enterprises (CROPS) also appears to be positively related with use. Prediction success in the OFTEN model was 58.5% and decreased with increasing frequency of use: Producers that used a computer a few times a year (OFTEN = 0) and a few times a month (OFTEN = 1) were predicted with 68.2 and 54.5% accuracy, respectively. The OFTEN model was approximately twice as good as a random estimate for those producers using their computers weekly (OFTEN = 2, 43.8% correct) but equal to a random guess for producers using computers daily (OFTEN = 4, 25.0% correct).

In the number of software applications (NUMAPPS) logit model, technical or vocational education (EDU2), size of operation (SALES), PCSKILL, and USEFUL were significant at greater than the $\alpha = 0.10$ level. Each of these explanatory variables had a positive impact on the number of software applications used. One-third of producers use seven or more software applications, and 70% use at least five applications (Ascough et al., 1999). Although not statistically significant, less farming experience (EXPYRS), a college degree (EDU4), and operator as the primary user (OPERATOR) all appear to contribute to more software applications used. Prediction success was lowest in the NUMAPPS logit model (51.7%). The number of software applications used was predicted correctly about half of the time for all categories, except for those that use their computers for only one or two applications (NUMAPPS = 0).

DISCUSSION

We posed the following questions at the beginning of this paper that are important to agricultural software developers: Which producers are using computers, and how do they use them? How satisfied are producers with their computer's contribution to their agribusinesses? What are the implications with respect to software development? We devised our survey research based on previous studies that achieved moderate success at identifying farm or farmer characteristics to predict whether producers would adopt computers or whether they would find them useful. In our previous computer adoption research (Hoag et al., 1999; Ascough et al., 1999) based on the 1996 Great Plains survey, we found that it was much harder to predict whether a producer would adopt a computer than it was in earlier studies. The most important predictors of adoption in previous studies, education and experience, were no longer significant, leading to our observations that: (i) adoption has caught up with households, and producers no longer seem to be limited by education or exposure to computers; and (ii) adoption does not appear complete, necessarily, because some producers still cited difficulty to learn computer hardware and software as significant obstacles. We reached the conclusion that "future research and education should focus on when and where computers are most needed, and therefore when adoption is most appropriate" (Hoag et al., 1999, p. 57). The above statements have significant ramifications for agricultural software development: In general, developers have had limited success (in purchase and use of their software) because of a failure to correctly identify when and for what reason computers are needed on the farm or ranch. Despite the vast array of available software applications, producers seem more willing to use computers for record-keeping and financial analysis than for direct help in making decisions (Ascough et al., 1999). As shown in Table 3, about three-quarters of producers use software for taxes, accounting, record-keeping, etc., and more than half use computers for production records and financial planning. Approximately one-quarter use software to assist with production decisions.

We extended our 1996 survey of Great Plains producers to examine producer computer use and satisfaction and discuss potential implications for agricultural software developers. Building on our earlier computer adoption research, we developed ordered logit models for user satisfaction, frequency of computer use, and number of software applications used. Despite using more robust models (e.g., independent variables are treated as ordered scales, thereby addressing the ordinal nature of frequency of use and number of software applications used), surprisingly few explanatory variables were significant. Greater computer skill significantly increased user satisfaction and number of software applications used. Greater education also increased user satisfaction and number of software applications used but reduced frequency of use. Farming experience showed similar conflicting results as education, i.e., greater number of years farming resulted in significantly increased computer satisfaction but lower frequency of use and number of software applications used. A few other variables (e.g., farm owner or operator as the primary computer user had a significant positive influence on frequency of use) were important in one of the three ordered logit models, but no consistent relationship between models was found. Generally, greater frequency of use and computer skill increased perceived usefulness of computers by producers.

Table 3. Frequency and type of software use by computer adopters (adapted from Ascough et al., 1999).

Item	Never	Yearly	Monthly	Weekly	Daily
			%		
Overall	**5**	**31**	**35**	**21**	**8**
Taxes	**26**	**20**	**45**	**6**	**1**
Accounting or record-keeping	**15**	**3**	**56**	**22**	**3**
Production records (payroll, billing, etc.)	**43**	**19**	**27**	**9**	**2**
Financial planning	**44**	**22**	**26**	**6**	**1**
Production decision aids (feed rations, irrigation management, etc.)	**75**	**5**	**14**	**5**	**1**
Electronic marketing news	**84**	**0**	**3**	**4**	**9**
Electronic weather information	**83**	**0**	**1**	**4**	**12**
Word processing	**11**	**5**	**38**	**38**	**8**
Spreadsheets	**27**	**8**	**40**	**20**	**5**
Online services (Internet, Compuserve, etc.)	**89**	**0**	**0**	**4**	**7**
Online services (Internet, Compuserve, etc.)	**71**	**3**	**8**	**10**	**9**

These results potentially have important implications for agricultural software developers. First, given that only about 25% of producers (that own computers) use any type of decision aid software, and this is for highly specialized purposes such as irrigation and livestock management, it is clear that many production and management decisions are being made without assistance or support from computer software programs. Therefore, we can surmise that the efficacy and value of this type of agricultural software has not been sufficiently demonstrated to producers. Many factors are involved in the willingness of producers to adopt and use decision aid software, and while our data do not directly address this issue, we can provide additional insight into the answer. Second, are agricultural software developers correctly targeting the likely users? Generally, it is perceived that the progressive farmer is the initial target user. Yet, producers with the greatest education level and farming experience and with the most invested in their operations (i.e., highest ownership of modern computer hardware and farm equipment), while satisfied with their computers and having a high computer skill level, use their computers less frequently with a lower number of software applications. Perhaps this is another validation that perceived usefulness of agricultural software decision aids does not override producer managerial ability developed through experience and education? Third, if agricultural software developers wish to have their software purchased and used, they must address the computer skill level of producers. Any perceived difficulty with using computer hardware or agricultural software will likely result in poor acceptance and lack of use. Many decision aid software tools that attempt to meaningfully supplement the producers' knowledge base are often complicated to use. Extensive training probably will need to be provided for producers to consider purchasing specialized agricultural software. Lastly, we uncovered no significant pattern helping to direct which types of agricultural software would be most widely accepted and concluded that market niches for agricultural software have not emerged for specific farm or farmer characteristics. Finding general niches or widespread acceptance will require more effort on the developers' part to demonstrate benefits relative to costs (i.e., create the demand).

CONCLUSIONS

Producer adoption rate of computers has steadily grown in the last two decades and now equals the general population. However, software applications primarily used by producers are for taxes, record-keeping, word processing, and spreadsheets, with low ownership and use of specialized agricultural software. For example, only about 25% of producers with computers use decision aid software tools, and these are very specific applications such as irrigation or livestock management. Investors who contribute financial and human resources for agriculturally related software research and development hope to find an appropriate market niche; our study suggests that previous differences in the types of farms or farmers who adopt and use computers no longer are useful guides for agricultural software developers. The most important factors now are computer skill level, amount of education, and years of farming experience, but only computer skill level did not show conflicting relationships with computer satisfaction, frequency of use, number of software applications used, and ultimately, the value of computers to producers.

With low ownership and use of agricultural decision aid software as an example, we believe the merit of most agricultural computer software has not yet been proven to producers, or at least not sufficiently for them to expend the effort to purchase and learn specialized software. Even if computer literate producers are targeted for agricultural software use, this market is likely marginal both in terms of size and interest. Agronomists and others who develop and transfer agricultural software may have to be content with limited applicability or will need to spend more time, money, and effort on research and development to discover where specific producers interests and needs lie. Future efforts might be better served if developers focus on lowering costs and raising benefits from the producers' perspective.

REFERENCES

Acock, B., Y. Pachepsky, E. Mironenko, F. Whisler, and V. Reddy. 1999. GUICS: A generic user interface for on-farm crop simulations. Agron. J. 91:657–665.

Amponsah, W. 1995. Computer adoption and use of information services by North Carolina commercial farmers. J. Agric. Appl. Econ. 27:565–576.

Ascough II, J.C., D.L. Hoag, W.M. Frasier, and G.S. McMaster. 1999. Computer use in agriculture: An analysis of Great Plains producers. Comput. Electron. Agric. 23:189–204.

Baker, G. 1992. Computer adoption and use by New Mexico nonfarm agribusinesses. Am. J. Agric. Econ. 74:737–744.

Batte, M. (ed.) 1995. Adoption and use of farm information systems. North Cent. Regional Res. Publ. 339. OARDC Spec. Circular 149. The Ohio State Univ., Columbus.

Batte, M., E. Jones, and G. Schnitkey. 1990. Computer use by Ohio commercial farmers. Am. J. Agric. Econ. 72:935–945.

Davidson, R., and J.G. MacKinnon. 1993. Estimation and inference in econometrics. Oxford Univ. Press, New York.

Dillman, D. 1978. Mail and telephone surveys: The total design method. Wiley-Interscience, John Wiley & Sons, New York.

Greene, W.H. 1999. Econometric analysis. 4th ed. Prentice Hall Publ. Co., New York.

Hoag, D.L., J.C. Ascough II and W.M. Frasier. 1999. Farm computer adoption in the Great Plains. J. Agric. Appl. Econ. 31:57–67.

Jarvis, A. 1990. Computer adoption decisions—implications for research and extension: The case of Texas rice producers. Am. J. Agric. Econ. 72:1388–1394.

Magari, R., and M. Kang. 1997. SAS-STABLE: Stability analyses of balanced and unbalanced data. Agron. J. 89:929–932.

Michel, B., and D. Radcliffe. 1995. A computer program relating solute potential to solution composition for five solutes. Agron. J. 87:126–130.

Putler, D., and D. Zilberman. 1988. Computer use in agriculture: Evidence from Tulare County, California. Am. J. Agric. Econ. 70: 790–802.

Schmidt, D.R., S.K. Rockwell, L. Bitney, and E. Sarno. 1994. Farmers adopt microcomputers in the 1980's: Educational needs surface for the 1990's [Online]. Available at http://www.joe.org/joe/1994june/a9.html (verified 5 Aug. 2002). J. Ext. 32(1).

Schulthess, U., K. Schroeder, A. Kamel, A. AdbElGhani, E.E. Hassanein, S.S. AbdElHady, A. AbdElshafi, J. Ritchie, R. Ward, and J. Sticklen. 1996. NEPER-Weed: A picture-based expert system for weed identification. Agron. J. 88:423–427.

Smith, J.U., N.J. Bradbury, and T.M. Addiscott. 1996. SUNDIAL: A PC-based system for simulating nitrogen dynamics in arable land. Agron. J. 88:38–43.

USDA–National Agricultural Statistics Service. 2001. Farm computer usage and ownership. USDA-NASS Agric. Stat. Board, USDA, Washington, DC. (Available online at http://usda.mannlib.cornell.edu/reports/nassr/other/computer/empc0701.pdf; verified 5 Aug. 2002.)

Wilkerson, G.G., S.A. Modena, and H.D. Coble. 1991. HERB: Decision model for postemergence weed control in soybean. Agron. J. 83:413–417.

Willimack, D. 1989. The financial record-keeping practices of U.S. farm operators and their relationship to selected operator characteristics. *In* Proc. Am. Agric. Econ. Assoc. Annu. Meet., Louisiana State University, Baton Rouge, LA. 31 July–2 Aug. 1989.

Woodburn, M., G. Ortman, and D. Levin. 1994. Computer use and factors influencing computer adoption among commercial farmers in Natal Province, South Africa. Comput. Electron. Agric. 11: 184–194.